Land Suitability Analysis for Cumin Production in the North Khorasan province (Iran) using Geographical Information System

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ABSTRACT: The land suitability of agricultural lands of the North Khorasan Province (Iran) for cumin production was assessed. For this purpose, Digital elevation model (DEM) was provided from 1/25000 digital maps and surface analysis functions were used to create topographic layers and multiple regression models were provided, tested, and used to create rainfall, average temperature, and extreme temperatures layers for cumin growing season. Three Scenarios were used to determine land suitability of study area for cumin production. (1): areas with minimum temperatures ≥ 3 °C in January, February, and March, rainfall ≤ 160 mm, slope ≤ 15% and South and east aspects. (2): areas with minimum temperatures ≥ 3 °C in March, rainfall ≤ 160 mm, slope ≤ 15% and South and east aspects. (3): areas with minimum temperatures ≥ 3 °C in March slope ≤ 15% and South and east aspects. Scenario I was considered to provide probability map of cumin cultivation in the best climatic and topographic conditions. Scenario II was considered for March sowing date onward, and January and February sowing dates were avoided. In scenario III, we assumed that fungal diseases which are resulted from high soil moisture content after receiving more than 160 mm rainfall will control by different management options. Our results indicated that pre-March sowing dates are not advised, because the probability maps of extreme temperature occurrence showed these regions are high risk and vulnerable. Only 6.2 and 21.9 % of total agricultural lands were detected as favorable regions for cumin production base on Scenarios of II and III, respectively. Our results indicated that according to special needed considerations to sow cumin in the regions were detected by II and III scenarios, and reducing the cumin yield in late sowing dates, it seems this medicinal crop could not be advised to extend its cultivation in medicinal plants extending program in this province. Our results revealed that GIS–based plans can help us to create a shortcut for conscious decision making in large scales, which is a necessity for new crops, especially medicinal plants such as cumin.

Keywords: Cuminum cyminum, Land evaluation, GIS, climatic restriction

INTRODUCTION

Cumin is an annual Umbelliferous plant commonly cultivated in arid and semi-arid regions of Iran, especially in Khorasan provinces. The crop is generally grown in sandy loam to clay soils during the winter season using irrigation (Lodha, 1995). Despite the relative importance of this medicinal plant in crop rotations of arid and semi-arid regions and many advantages such as low water requirements and its high value in agricultural exports, it has not been adequately studied and there is not much information on potential yield of the current cultivated area (Kamkar et al., 2011). On the other hand, land suitability assessments as the first step of land use plan has not considered yet.

Crops grow best in locations where the climatic conditions meet their growth requirements. Elevation, slope, aspect, soil (pH, drainage and texture), landcover and many climatic factors that affect crop growth, help in determining the most suitable crop growth areas. The process of land suitability classification is the evaluation and grouping of specific areas of land in terms of their suitability for a defined use. The main objective of the land evaluation is the prediction of the inherent capacity of a land unit to support a specific land use for a long period of time without deterioration, in order to minimize the socioeconomic and environmental costs (de la Rosa, 2000).

There are various ways to estimate the extent of land with cultivation potential. Any
quantification would depend upon a variety of assumptions. Since land suitability analysis requires the use of different kind of data and information (soil, climate, land use, topography, etc.), the geographic information system (GIS) offers a flexible and powerful tool than conventional data processing systems, as it provides a means of taking large volumes of different kinds of data sets and manipulating and combining the data sets into new data sets which can be displayed in the form of thematic maps (Marble et al., 1984; Foote and Lynch, 1996). The topographic characteristics, the climatic conditions and the soil quality of an area are the most important determinant parameters of the land suitability evaluations. Use of GIS allows the construction of models from which a new thematic map (e.g. land suitability map) can be produced from a set of thematic maps (Harasheh, 1994). The present study was, therefore, undertaken with the objective to delineate suitable production areas for cumin production in the North Khorasan province, Iran.

The AEZ concept involves the representation of the components of land as layers of spatial information or map layers and the integration of the layers using a Geographic Information System (GIS). The combination or overlay of layers produces agroecological cells that represent basic land units with specified characteristics. In this way a land resources database is created containing information on the AEZ cells (Food and Agriculture Organization of the United Nations).

**METHOD**

The study area, state of the North Khorasan province is a mountain state with an altitude ranging from 378 to 2823 m above mean sea level. The geographical configurations of the North Khorasan province extend from 36.57° N. to 38.27° N. latitude to 56.06° E. to 58.41° E longitude (Fig.1.). The different geo-physical and climatic parameters viz., precipitation and temperature, topographic (elevation) and land use were used for identifying suitable areas for cumin. Elevation (digital elevation model-DEM) was derived from the interpolation of contour lines and spot heights which were derived from 2-D and 3-D digital maps (Scale: 1:25000). Climatic data also were derived from daily meteorological data from seven synoptic and climatologic stations.

All digital data and analyses were conducted using ArcGIS9.3.1 software. Vector data were obtained for boundary lines. The vector data were all in 1:25000 scales and were in Universal Transverse Mercator projection and WGS_1984 datum.

Slope and aspect were derived by related functions in spatial analysis using Digital Elevation Model (DEM) with a pixel size of 10 m.

Historical meteorological data obtained from seven non-automatic weather stations. These data were interpolated to calculate meteorological data for all the map squares. For this purpose, multiple regression method was applied. In this case, each variable (including mean temperature, minimum temperature, maximum temperature and precipitation) were related by correspondent coordinates and elevation data. Then different combinations were tested to obtain the least squared difference between observed data minus simulated one. Then a 10 by 10 net was constructed on DEM to extract centroid points. For this purpose, "Add XY coordinates" and "extract values by points" functions were used. Then all meteorological variables were calculated by "raster calculator" procedure and then were interpolated by spline function. All climatic layers were combined by cell statistics function as needed. These data were combined to calculate mean temperature values (average, minimum and maximum values) and sum of precipitation during growing period of cumin.

Cardinal germination temperatures were determined by fitting an intersected lines model to germination rate at seven constant temperatures (varying from 5 to 35 °C, with 5 °C intervals). This independent experiment was carried out at the Faculty of Agriculture, Ferdowsi University of Mashhad, Iran in 2001 in a four replicated completely randomized experiment. Iterative optimization procedure was applied to estimate equation parameters by NLINDUD procedure in SAS (1990).

Extreme temperatures layers also were provided to find appropriate cumin sowing date. These temperatures are important to successful establishment of cumin and were considered as temperature bins in reclassified layers which were used in weighting overlay function. Three scenarios were used to detect favorable and unfavorable areas in the North Khorasan province: (I): areas with minimum temperatures ≥ 3 °C in January, February and March, rainfall ≤ 160 mm, slope ≤ 15% and South and east aspects. (II): areas with minimum temperatures ≥ 3 °C in March, rainfall ≤ 160 mm, slope ≤ 15% and South and east aspects. (III): areas with minimum temperatures ≥ 3 °C in
March, slope ≤ 15% and South and east aspects. Scenario I was considered to provide probability map of cumin cultivation in the best climatic and topographic conditions. Scenario II was considered for March sowing date onward, and January and February sowing dates were avoided.

In scenario III, we assumed that fungal diseases which are resulted from high soil moisture content after receiving more than 160 mm rainfall will control by different management options.

![Fig 1. Study area coordination and position on Iran map and its land use.](image)

**RESULTS AND DISCUSSION**

The North Khorasan province is characterized by cool winter and variable precipitation values. Cold temperatures during January and February could be a main cause of late or failed establishment of many crops, especially when low temperatures events are occurred along with high soil moisture contents. Therefore, these two months were considered in respect to low extreme temperatures which their occurrence is probable. Also March month also was tested in respect to extreme low temperatures for cumin production.

Minimum temperature layers for January, February and March were queried together to find areas with tmin ≥ 3 °C as the base temperature based on data were obtained from intersected line model. The base, optimum and ceiling temperatures of cumin pre-emergence were determined as 3.5 °C, 15 °C and 30 °C. Our results indicated that just 6.18% of total agricultural lands of the North Khorsan Province (36094 ha) were detected as favorable lands (Fig. 2). These results confirmed that minimum temperature is one of the most limiting factors which should be considered in the North Khorasan province. Temperature changes drastically in the first few tens of millimeters from the surface into the soil or into the air and this can affect cumin seed germination and seedling establishment. This is especially important when soil moisture content also is high. This situation is common for the North khorasan province. East and South aspects were considered as superior aspects to sow cumin. Our results indicated that totally 42.7 % of total agricultural lands were located in these aspects (Fig. 3). The slope map which extracted for slope<15 % also revealed that around 82.2% of agricultural lands (415825 ha) were in appropriate range (Fig. 3). Therefore, it seems slope can not affect cumin cultivation significantly in the North Khorasan province. One of the most important factors which affect cumin fields is incidence of fungal diseases specially *Fusarium oxysporum* spp. Stepwise regression on yield gap as dependent variable and fungal infection, weed infestation, common practices, sowing date, salinity and successive planting as independent variables which affect yield gap (Kamkar et al., 2011) showed that fungal diseases, successive planting and sowing date could be used to interpret 73% of yield gap variation in 228 fields of Khorasan provinces. Also, their results indicated that 1% of the fungal infection increase equals to 150 kg per hectare yield loss. Therefore, these were considered as the main reducing or limiting factors in study
regions with 38% contributed by fungal diseases, 30% by sowing date and 5% by successive planting. Lodha et al. (1986) also reported that losses due to wilt (*Fusarium oxysporum* Schl. f. sp. cumini Prasad and Patel) alone may reach 40%. Therefore if fungal disease can be avoided by appropriate management options, the agricultural lands which are suitable for this crop will increase. Therefore in a scenario (Scenario I), rainfall ≤ 160 mm was considered as one of the most important determinant factors in land suitability for cumin production in Khorasan province. Our results indicated that mean precipitation was changed in the range of 111.5 to 229.2 mm during cumin growing season. Tavousi (2000) showed that in normal years with around 160 mm precipitation, additional irrigation is not necessary to produce cumin. Therefore, water supplied at more than 160 mm can be a cause of fungal infection in cumin fields of Khorasan provinces. Provided map showed that around 85.3% of agricultural lands receive more than 160 mm precipitation. Therefore, this can be a serious concern for cumin production systems. Our results indicated that the west side of the North Khorasan province is more vulnerable than the east side in respect to probable infection by fungal disease. When all affecting factors including climatic and topographic factors were overlaid by Boolean method, three applied scenarios showed different land suitability. When all factors including higher temperature than 3 °C in January, February and March, Slope ≤ 15%ar, east and south aspects and rainfall ≤ 160 mm were considered, any suitable area was not detected, while for March sowing dates onward, only 6.2% of agricultural lands were detected as favorable. When fungal diseases concern also was eliminated from overlay (Scenario III), 21.9% of all agricultural lands were recognized as favorable lands (Fig. 4).

![Map of North Khorasan Province](image_url)

**Fig. 2.** Favorable and unfavorable areas of the North Khorasan Province in respect to Tmin ≥ 3 °C in both January and February (above) and in March (below).
Fig. 3. Reclassified layers of aspects and slopes in the North Khorasan province.

Fig. 4. Suitable areas for cumin production in the North Khorasan province based on Scenario II and Scenario III.

**DISCUSSION**

Overall, our results indicated that cumin can be cultivated in the North Khorasan province by many considerations. The maximum area which can be cultivated by cumin under special consideration and managements are equal to 21.9% of total agricultural lands. Sowing date is restricted to march sowing dates onward and pre-March sowing dates will face cumin fields by many problems such as late germination and emergence and prolonged seedling growth. Our
results indicated that minimum temperature of March in agricultural lands of the North Khorasan province changes from -1.6 to 14.2 °C. On the other hand, high rainfall during cumin growing season is another restriction because of probable fungal diseases. Our results indicated that the regions which are located in the west side of studied province were unfavorable for cumin production (especially by scenario II). Fungal diseases upon unawares and sometimes fail fields completely. For instance, Champawat (1990), in a two-year experiment to screen 161 cumin germplasms against F. oxysporum f. sp cuminum, showed that among them four and three germplasms were semi-tolerant and sensitive, respectively, while the remainder were hypersensitive. Kamkar et al., (2011) showed that F. oxysporum and Alternaria burnsi were the most important fungal diseases that reduced cumin yield in the Khorasan provinces. Their results on fungal disease showed that 67% of surveyed fields (averaged for all fields) were infected with both diseases and the percentage of infected fields to both fungal diseases (simultaneous infection) changed with latitude and infection increased with increasing latitude and tended to increase when moving from warmer and dryer to cooler and wetter regions. Our results also confirmed these results. Also our results indicated that if cumin cultivation is advised based on scenario III, all possible managements should be taken to reduce damage by Fusarium spp. The disease control measures includes nutrient manipulation through amendments or modification of the soil environment (Engelhard, 1989), solarization, biocontrol (Chet et al., 1982), the application of metasodium (Frank et al., 1986), crop rotation (Katan et al., 1983), and application of three essential oils (cumin, basil and geranium) (Hashem et al., 2010).

Overall, it seems that cumin is not advisable to extend its cultivation in the North Khorasan province. The results of other reports have shown that late sowing dates (from January onwards) is not advisable (Rahimian Mashhadi, 1991; Mollafabili, 1993). This crop has detected as a facultative long day plant and by late sowing, flowering will occur soon. With considering all aforementioned affecting factors and with focusing on the effect of late sowing dates on yield reduction in cumin fields, it seems that this medicinal crop is not advisable in medicinal crops extending programs which has considered by the excellence center of special crops in Khorasan provinces.

REFERENCES


Foote KE, Lynch M. 1996. Geographic information systems as an integrating technology: context, concepts and definition. Austin, University of Texas


Mollafabili A. 1993. Effects of Sowing Date and Row Spaces on Cumin (Cuminum cyminum) Yield under Rainfed and Irrigated Conditions. Scientific and industrial research center of Iran, Khouran in (Persian with English abstract).

